BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 09047

SUBJECT: Simultaneous Detection of Lunar Seismic and Transient Gas Events - Case 340

DATE: September 18, 1970

FROM: G. K. Chang
T. T. J. Yeh

ABSTRACT

Possible near-simultaneous occurrence of lunar seismic events and transient gas venting in the Fra Mauro region at times of maximum tides was recently suggested by Dr. G. Latham of Lamont-Doherty Geophysical Observatory. We suggest herein that two Apollo 14 ALSEP experiments, the Passive Seismic Experiment (PSE) and the Cold Cathode Gauge Experiment (CCGE), may be used to test the validity of Latham's suggestion.

The Apollo 14 landing is scheduled for early 1971 in the Fra Mauro region, (3°40'S/17°29'W). Geological evidence indicates a potential transient gas source near the southern edge of the Fra Mauro crater, about 100km south of the proposed landing point. A simplified analysis of gas transport on the lunar surface indicates that Ne or lighter gases released there at a temperature of 250°K would have a range of 100km or greater and thus be detectable by the CCGE. Heavier gases, such as Ar or CO_2, would require a gas temperature above 300°K to reach this distance. To increase the probability of detecting these near-simultaneous events, the CCGE should be deployed on a line between the LM and the suspected gas source with the CCGE entrance aperture facing away from the LM. Deployed in this fasion, the CCGE could detect from a distance of 100km a source that releases gas at a rate of at least 2gm/sec. If reports of lunar gas fluorescence can be relied on, the gas effusion rate should be on the order of 10^3gm/sec and the suggested gas venting should be easily detectable.

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MEMORANDUM FOR FILE

Introduction

Recently, Dr. G. Latham, the principal investigator for the Passive Seismic Experiment (PSE), reported that certain seismic events recorded by the PSE correlate with the time of earth-moon perigee. He has suggested that these are caused by a sudden release of tectonic stress due to a maximum tidal strain during perigee passage. Latham further suggests that the seismic events are related to lunar transient gas events (release of trapped subsurface gases), and that the source of both may be located in the Fra Mauro region.(1) Although a transient event in this region has not been reported(2), analysis of geological features in the southern rim region of Fra Mauro crater indicates a possibility of such an occurrence(3).

In an attempt to correlate lunar seismic and transient events, Latham requested astronomers to focus their telescopes on the Fra Mauro area around the time of earth-moon perigee. In this memorandum we examine an alternate method of testing the correlation between the lunar seismic and transient gas events, namely use of the PSE and the Cold Cathode Gauge Experiment (CCGE) on the Apollo 14 ALSEP which is scheduled to be emplaced early in 1971 at 3°40'S/17°29'W, about 70km north from the center of the Fra Mauro crater.

ALSEP Experiments

On Apollo 14, the ALSEP consists of the PSE, the CCGE, the Active Seismic Experiment (ASE), the Charged Particle Lunar Environment Experiment (CPLEE) and the Suprathermal Ion Detector (SIDE), which will be deployed on the lunar surface to collect scientific data for a period of one to two years. The PSE will measure the lunar surface motion due to an internal energy release or an external impact source. The CCGE will measure the density of neutral gas in the lunar environment, generated by a steady state source or derived from a transient origin.

Gas Transport on the Lunar Surface

Since we have no *a priori* knowledge of the nature and rate of gas released from the subsurface, we only make a rough analysis of the gas transport on the lunar surface. We assume the particles are emitted isotropically from a vent with a mean speed $\bar{v}$ characterized by the gas temperature T. Assuming the gas to be Maxwellian, the mean speed of the gas $\bar{v}$ is given by:

$$\bar{v} = \sqrt{\frac{8kT}{\pi m}}$$

where k is Boltzmann's constant and m is the molecular weight of the gas. The mean speed of the gas as a function of temperature for various possible gas species is plotted in Figure 1.

We further assume that the particles suffer no collisions or ionizations from the time they leave the lunar surface to the time they return to the surface. Thus, all particles travel in ballistic trajectories. The maximum range, D, that a particle with a given speed $\bar{v}$ can travel on the lunar surface is given by(4),

$$D = 4R\beta,$$

and,

$$\beta \equiv \arc\tan \sqrt{\frac{1-\sqrt{1-\bar{v}^2R/\mu}}{1+\sqrt{1-\bar{v}^2R/\mu}}},$$

where R is the lunar radius and μ is the lunar gravitational constant. The maximum ranges for the gases considered at temperatures ranging from 250 to 500° K, are plotted in Figure 2. The time-of-flight, t_f, for a particle traveling the maximum distance is given by,

$$t_f = 2\sqrt{\frac{R^3}{\mu}}\left(2-\frac{\bar{v}^2R}{\mu}\right)^{-3/2}\left[\arc\cos\frac{\cos(\pi/4+\beta)}{\cos(\pi/4-\beta)} + \right.$$

$$\left. + \sqrt{\frac{\sin^2(\pi/4-\beta)}{\sin^2(\pi/4+\beta)} - \left(1-\frac{\bar{v}^2R}{\mu}\right)^2}\ \right]$$

Figure 3 presents a plot of t_f computed for gas speeds ranging from .25 to 1.6km/sec.

Detection of Lunar Gas Venting in the Fra Mauro Area by the Apollo 14 CCGE

Based on geological evidence, Head[3] found that the most probable location of a transient gas source in the Fra Mauro region is near the southern edge of the Fra Mauro crater. Head also pointed out that several other rilles in the Fra Mauro region could also be sources of transient gas. However, in this discussion we assume the primary gas source to be near the southern edge of the Fra Mauro crater, about 100km south of the scheduled Apollo 14 landing point.

In this case, the gases that could be detected by the CCGE would be Ne or lighter gases, if the gas temperature is less than 250°K. Here we have considered only the "primary" particles, that is, particles in direct ballistic orbits from the source. The "secondary" particles are most likely the product of diffuse scattering by the surface, and it can be shown that the densities of the secondary particles at the CCGE are much smaller than those of the primary ones.

To ensure detection, heavier gases such as Ar or CO_2 must have a temperature above 300°K, for, as shown in Figures 1 and 2, gas particles that travel distances of 100km must have an average speed of at least .4km/sec, regardless of their mass. At gas temperatures below 500°K, heavy gases such as Kr or Xe will have little chance of being detected by the CCGE at distances greater than 80km from their source. Gases of volcanic origin may have much higher temperatures; however, we do not consider this in the present discussion.

The CCGE measures the total gas density, but not the composition. We shall for the moment, ignore in this discussion the species of gas and assume that all particles have the same speed, namely, the thermal speed of .4km/sec. On the basis of this assumption, we shall estimate the minimum detectable rate of gas release at a source 100km away. The ultimate sensitivity of the CCGE is about 10^{-12} torr pressure, equivalent to about 1.3×10^{-9}gm/cm-sec^2. The corresponding mass flux calculated for a particle velocity of .4km/sec is about 3×10^{-14}gm/cm^2-sec. The required rate of gas release at the source for an isotropic gas flow from a vent is obtained by multiplying the above mass flux by the total area of a hemisperhic surface of appropriate radius. The minimum rate of gas release to be detected by the CCGE 100km distant from the source is then about 2gm/sec.

2gm/sec is an order of magnitude smaller than the rate of gas release during LM depressurization. Approximately 3kg of gas are released in 100 seconds when the LM is depressurized prior to the EVA period[5]. Since the ALSEP will be deployed at most a few hundred meters from the LM, a large dynamic pressure will result from the LM depressurization. After LM Ascent Stage liftoff, the remaining Descent Stage could continue outgassing for an indefinite period. Since we have no precise knowledge of LM outgassing and no control over it, the CCGE entrance aperture should be facing away from the LM, thereby minimizing the possibility of LM outgassing products entering the CCGE.

The gas release rate of 2gm/sec is the minimum rate determined by the sensitivity of the CCGE; the actual gas release rate may be much higher. If the reports on lunar gas fluorescence can be relied on, one can estimate lower limits of the gas release rate. To be observed, the number of photons in a given bandwith $\Delta\text{Å}$, arriving in Δt sec at an earth based telescope from fluorescent molecules over a lunar area A, must be of the same order of magnitude as the number of reflected solar photons in the same bandwith intercepted by the telescope from the same area. In the red part of the solar spectrum about 3×10^{12} solar photons/cm^2-sec-Å are reflected by the lunar surface, characterized by an albedo of .07. Areas that were monitored for transient events, such as Alphonsus or Aristarchus[6], are typically on the order of 10^3-$10^4 \text{km}^2 = 10^{13}$-$10^{14} \text{cm}^2$. On the assumption that all molecules emanated from the source fluoresce while passing through these areas, we arrive at a lower limit of $\sim 3 \times 10^{25}$ particles/sec for the source yield of gas, detectable above the surface background near full moon. This corresponds to a limiting mass rate of $\sim 10^3$gm/sec, for particles of molecular weight near 20. This is a very conservative estimate, as compared, for instance with 10^{27}particles/sec estimated by Kozyrev on the basis of his 1958 observations of Alphonsus[7]. In any case, at such rates, the released gas should be easily detected by the CCGE.

As shown in Figure 3, a particle with a .4km/sec speed will travel a distance of 100km in about 6 minutes; a seismic pulse travels this distance in about half a minute[8]. Near-simultaneous recordings of a seismic signal by the PSE and a transient gas event by the CCGE with a time delay of about 5.5 minutes will indicate a simultaneous release of a seismic energy and trapped subsurface gas from a source at 100km away. In general a time delay, Δt, between events recorded by the PSE and the CCGE is an indication of distance of the detectors from the source of the event; the smaller the Δt, the shorter the distance, and _vice versa_. Since, in addition, the CCGE and the PSE will be in long term continuous operation, whereas telescopic observations are intermittent, they may furnish significant data on the correlation of lunar seismic and transient gas events, provided these phenomena are indeed related.

Conclusion

The CCGE is a suitable experiment for measuring transient gas that may be released from the lunar subsurface at the times of maximum tides, when a seismic event is recorded. Since the CCGE will also detect gases vented from the LM, the Apollo 14 ALSEP/CCGE should be deployed south of the LM with the CCGE entrance aperture facing south towards the hypothetical source, thus minimizing the possibility of detecting gases released from the LM.

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Attachments
References
Figures 1-3

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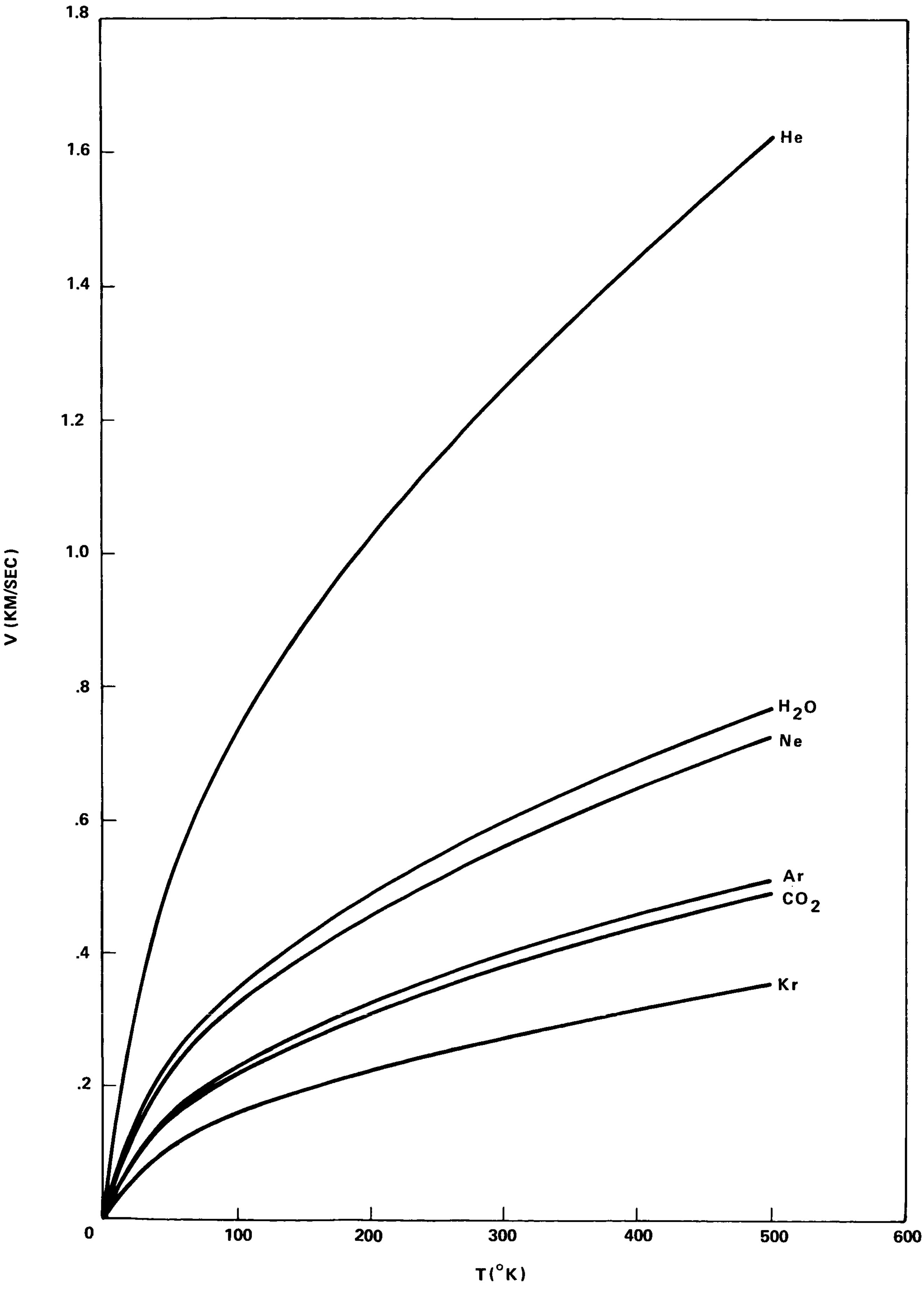

FIGURE 1– MEAN SPEED OF MAXWELLIAN GAS AS A FUNCTION OF TEMPERATURE

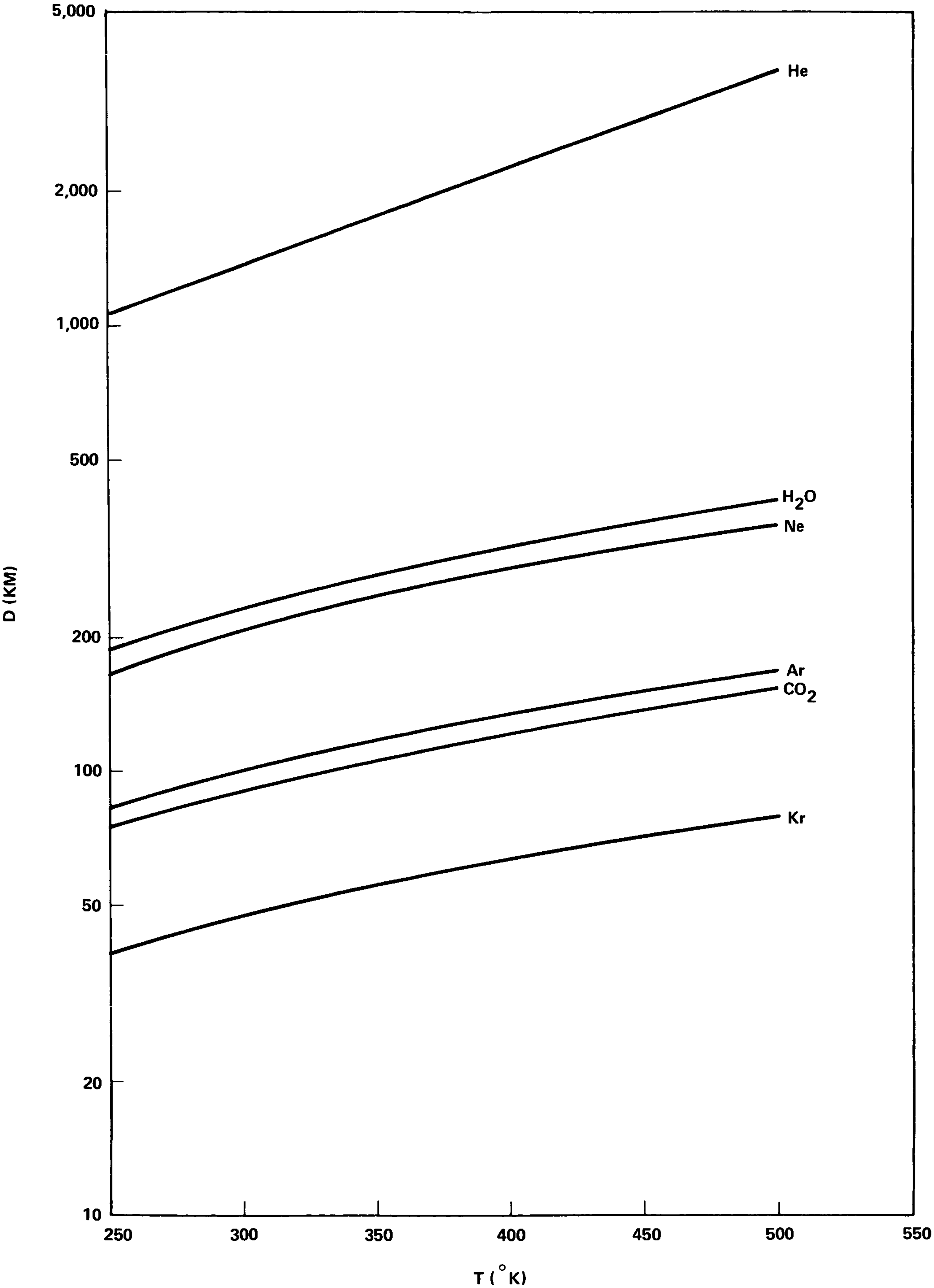

FIGURE 2 – MAXIMUM TRAVEL RANGE VS THE GAS TEMPERATURE

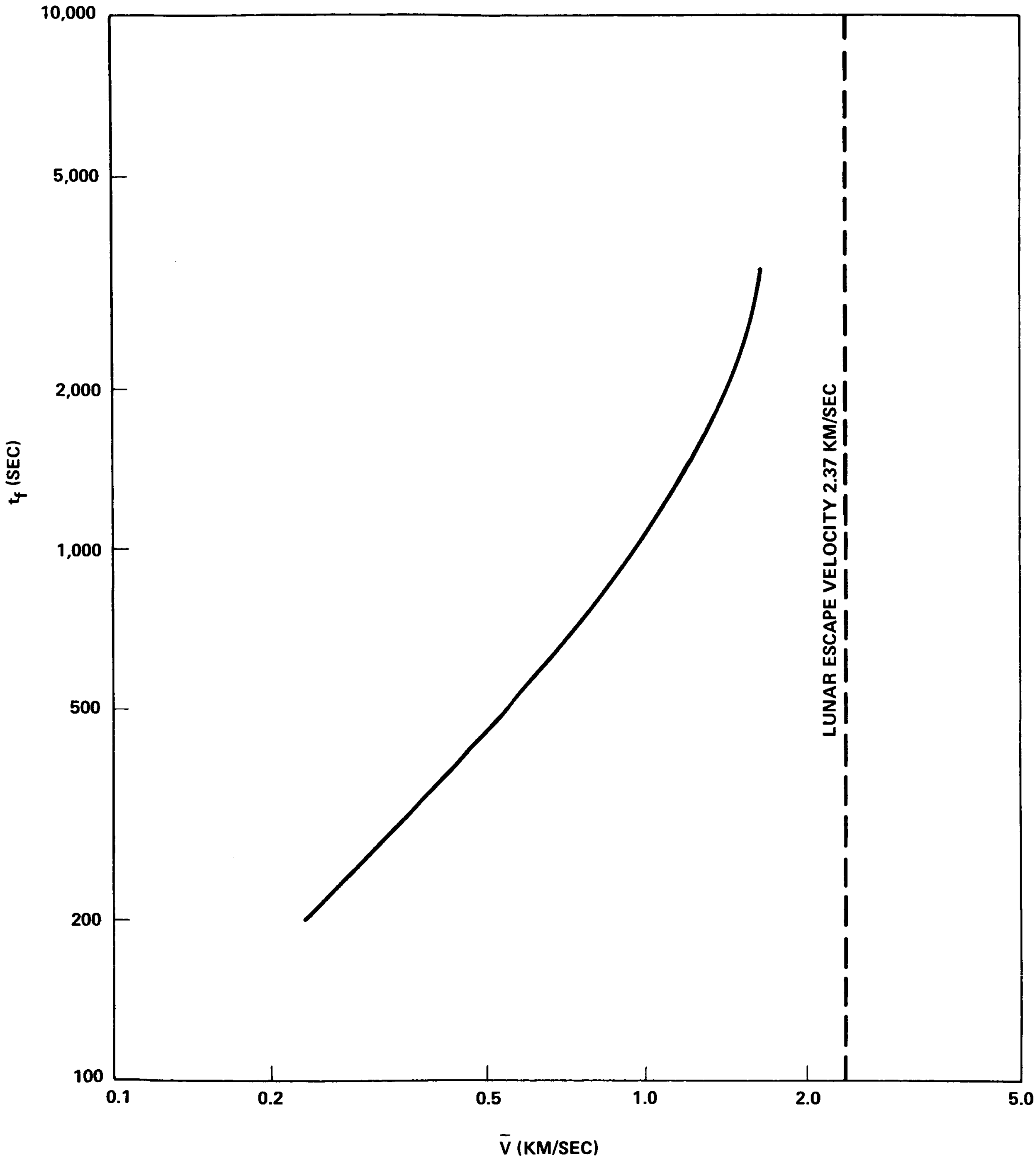

FIGURE 3 – TIME-OF-FLIGHT OF PARTICLE TRAVELLING TO ITS MAXIMUM RANGE